Lessons from the Field: The Contribution of Active and Social Learning to Persistent Energy Savings

Kyle MacLaury, Paul Cole, Emily Weitkamp and William Surles, Tendril

ABSTRACT

This paper documents three years of experience delivering residential behavioral efficiency programs enabled by real-time feedback paired with online tools. The technologies and strategies used represent a unique approach to behavioral strategies for energy efficiency that have achieved third party verified annual energy savings exceeding 9%. The technologies employed provide users with real-time feedback on electricity use via a website and optional in-home display. Users set savings goals and were provided feedback regarding their progress toward their goal through the website, and through optional daily, weekly and monthly emails. The social strategies utilized include anonymous comparison of a user's consumption to the average of similar households, the ability to take a *snapshot* of their energy consumption and post it to a community discussion board, and the ability to interact with an expert in an open forum. The features enable social and active learning, and help to maintain a high level of user interaction with the system. This study found an average of 9% reduction in electricity use compared to weather adjusted baseline use after 27 months in the program. The results demonstrate that individuals' level of engagement, measured as logins, correlates positively with energy savings. This paper also explores the ways in which users interacted with the participatory and interactive tools of the system, and how that contributed to the success of the program.

Introduction

Recent years have seen the beginning of a significant shift in the relationship between utilities and their customers. A number of forces within the industry are responsible for this. Efficiency mandates in many states require that utilities reach out to their customers and encourage them to change the way they use energy. Utilities' desire to invest in smart grid technology has introduced a need to provide their customers with tangible benefits of those substantial investments. In response to these forces, a number of solutions have been developed to connect utilities, their customers and the data generated by smart grid technologies. Many of those solutions are intended to help utility customers reduce their energy consumption through feedback, and a variety of educational and persuasive strategies. A recent review of several smart grid enabled feedback programs demonstrated a wide range of effectiveness in their ability to facilitate a reduction in utility customers' energy consumption (Foster & Mazur-Stommen 2012). This paper looks at the energy savings from the first two and a half years of experience with The Cape Light Compact Residential Smart Energy Monitoring Pilot, one of the programs described in that review. It also describes additional findings since the third party study of the program cited in that review (PA Consulting Group 2010), including several lessons learned from an exploration of how users interact with the various features of the website. The website employs a comprehensive behavioral approach and provides users with a variety of participatory and interactive tools that they can use on their own terms. The results suggest that these types of tools can lead to a successful residential feedback program that achieves high and persistent savings.

Energy Savings through Behavior Change

It is well established that occupant behavior is a significant source of the variation in residential energy consumption (Lutzenhiser & Bender 2008; Morley & Hazas 2011). A number of interventions have been shown to decrease energy consumption in people's homes through behavioral changes. Primary among those interventions is feedback about energy consumption. Feedback through a number of media, and a variety of frequencies and latencies have been shown to lead to decreases in energy consumption relative to groups receiving standard utility bills at their typical frequency. Enhanced bill design, increased bill frequency and instantaneous feedback through in-home displays have demonstrated impacts on residential energy consumption. The literature suggests that the more immediate and frequent the feedback, the greater impact on consumption (Ehrhardt-Martinez et al. 2010; Darby, 2006).

For behavioral energy efficiency methods to be fully accepted by the utility industry, the industry must be satisfied that behavioral changes are persistent and that they lead to the adoption of efficient technologies. Strengthening social norms through social interaction is one strategy to create persistent behavioral changes (Hopper & Nielsen 1991). By making information about peers' energy consumption visible, social comparisons begin to create social norms surrounding energy consumption where they did not previously exist. In recent years normative information has been integrated with feedback to significant effect. The use of descriptive norms in the form of neighbor comparisons has demonstrated effectiveness through the use of paper reports and electronic media (Allcott 2011).

Creating persistent behavior change also requires that new behaviors become habitual, and motivation to be internalized (De Young 1996). Addressing the intrinsic motivation of consumers can be achieved through goal-based methods. The social science literature about pro-environmental behavior indicates that to achieve persistent change goals, actions, feedback and social environment need to be addressed simultaneously (De Young 1993).

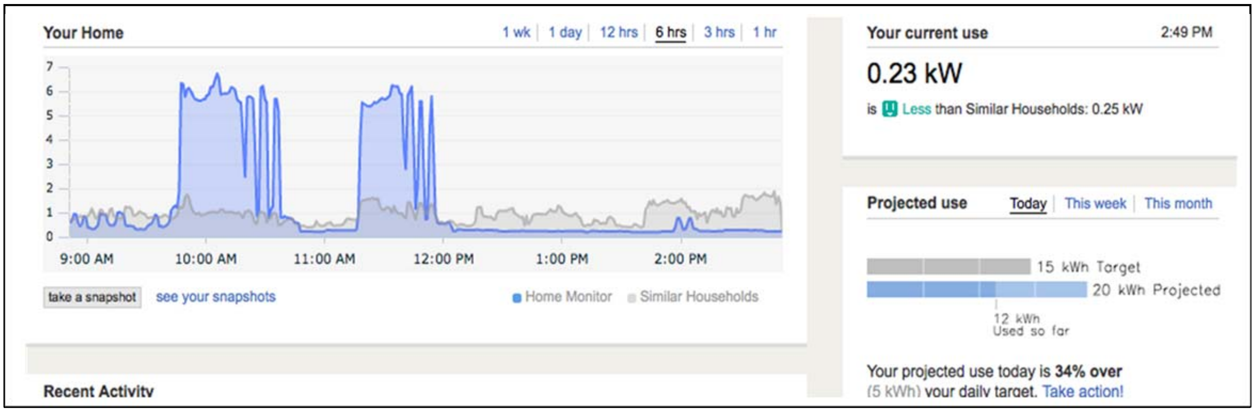
In addition to mediating behavior changes, a social environment is fundamental to the adoption of energy efficient technologies. The adoption of new technologies is largely a social phenomenon that is mediated by interactions in existing social networks (Rogers 2003). The slow adoption of many efficient technologies suggests that existing social networks are not supportive of their adoption. The creation of an online social network, where the use of new technologies is easily demonstrated and viewed, may provide members of the network sufficient social exposure to efficient technologies to facilitate their adoption.

This paper examines ways in which the various elements of a behavior-based energy efficiency application combine to influence a user's energy consuming behavior. The results demonstrate that a combination of elements delivered high levels of engagement and persistent energy savings after 27 months. They also suggest that this persistence arises from the high levels of participation. Participation is defined here as the ability to interact with energy use information and fellow energy users in a meaningful way.

The Application

The application was developed to demonstrate the potential benefits of combining behavior change strategies with the feedback that smart grid technologies enable. It combines feedback about energy use at several intervals (instantaneous, daily, weekly, monthly) and several modalities (in-home display (IHD), website, email) and incorporates a number of proven behavior change strategies into its design. The primary behavior change strategies incorporated into its design are: goal setting with frequent feedback about progress toward goal, feedback about energy consumption through several modalities and scales, peer comparisons, and educational materials including support from an online energy expert.

Figure 1. The Major Elements of the Dashboard



Source: www.save.groundedpower.com

In most cases, users had a current transformer (CT) based meter installed in the distribution panel of their home. (For a complete description of customer recruitment and installation see *Residential Smart Energy Monitoring Pilot Final Report* (PA Consulting Group 2010)). The meter is wirelessly connected to an Ethernet-enabled device that feeds consumption data to the web application. After the hardware was installed in a user's home, a welcome email with login information was sent to the user. When the user logged in for the first time they were asked to set a savings goal and answer a few basic questions about their home. Upon completion, the user could choose to complete a more extensive assessment of their home. This information was used to provide the user with a breakdown of how their home uses electricity, by end use, and also to target appropriate content to them. Once users have completed their home assessment they were taken to the *Dashboard* of the site. The site has six primary tabs (*Dashboard*, *Learn and Save*, *Your Savings Plan*, *Your Home*, *Your Town*, *Reports*). Only the most utilized of these features are discussed in this paper. The primary landing page for most users is the *Dashboard*, where users can see their current energy consumption, how they are performing relative to their goal, and a list of the most recent social activity on the website (see Figure 1).

Feedback and Goal Setting

Feedback and goal setting serve to make users' energy consumption more visible. This increased visibility serves to solidify users' associations between their energy consuming choices and those choices' subsequent impact on energy consumption. During their initial session on the website, users were required to choose a percentage savings goal. On the website the goal was presented as a daily or monthly kWh consumption limit and was calculated from the user's consumption during the corresponding month of the prior year. This goal was incorporated into the feedback users receive in several ways. Feedback was available to participants through their in-home display, on the website, and through periodic emails. The in-home display was color coded in such a way that it was green if the user was likely to remain below their goal for the day, yellow if they were in danger of exceeding their goal, and red if they were likely to exceed their goal. Through the website, users were able to view their real-time energy consumption in several locations. On the *dashboard* energy consumption could be viewed as; a numeric value; as a line graph of minute interval data that can be viewed at 1, 3, 6, 12 hour, 1 day and 1 week scales; and as a bar graph that showed the user's daily target, their consumption so far that day, and their projected consumption for the day (see Figure 1). Users could also use a *Reports* section of the website where they could view several standard graphs of their energy consumption, or download their consumption data as a csv file.

Emails

Every user received a monthly email that presented the user's consumption during the prior month compared to their goal. The email also provided a link to the reports tab on the website where users could explore their consumption in more detail. Users also had the option to receive weekly and/or daily emails. The weekly and daily emails could be opt-in or opt-out services depending on the utility client's preference. Some utilities chose to make the weekly email an opt-out service; while all chose to make the daily emails opt-in. The daily and weekly emails contained a user's consumption from the prior period compared to both their goal and the use of the other individuals in their comparison group. These emails also contained an energy saving tip.

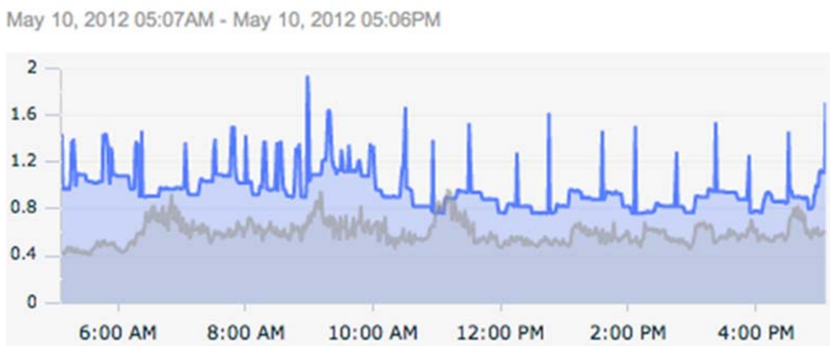
Social Comparison

The social comparison communicated a descriptive social norm to users. During a user's first session, they were required to answer a few brief questions about the size of the user's home and how many adults and children lived there. This data was then used to place the user into a peer comparison group. The neighbor comparison appeared most prominently on the line graph of the user's recent energy consumption found on the *dashboard* (see Figure 1). The comparison was also prominently featured in weekly and daily emails.

Social and Active Learning

The social aspects of the website were critical for the creation of new social norms around energy consumption. There were two primary features through which social interactions took place. The most frequently used social feature on the site was *snapshots*. A *snapshot* is a copy of a specific segment of the user's energy consumption profile. The user could add commentary to their *snapshot* that explains what was going on in their home during the period captured. Through *snapshots*, users were able to ask the experts and community for their experience or advice on what might be going on in their home, and how they could use that information to reduce their energy consumption. It was a frequent occurrence to have a user post a *snapshot* asking what the expert and other users thought was responsible for a given feature on their consumption graph. This often led to an extended period of discussion and discovery that included the expert and several users sharing their experience and asking questions to help narrow the search for answers (see Figure 2).

Figure 2. Mysterious Spikes Snapshot



Snapshot Taker: What are those mysterious spikes?

User 1: can it be a space heater?

Snapshot Taker: Nope. No dehumidifier. Was thinking it might be an icemaker – nope

User 2: A few observations... It's about 600 watts (so is likely a plug-in appliance), cycle is very brief (a minute or two) every 30-45 minutes, and appears to occur more frequently around breakfast time. Might be a coffeemaker (wattage is too low to be a toaster oven or instantaneous DHW heater) left on during the day: the heating element senses the need to cycle on more when the pot is often removed during mealtime, but only needs to add a bit of heat during the rest of the day to maintain pot temperature. Mmm... coffee... think I'll have a cup...

Resident Expert: User2 makes some great observations. Seems like this may just require some more detective work. Did the spike just start or have they been going on for a long time?

Snapshot Taker: found it…we have a hot water tap at the sink…and I guess every 30-40 mins it gooses the coil to keep the water hot. Thanks for the help

Source: www.save.groundedpower.com

The second space for social and active learning was through the Expert Forum, which was structured as a typical online forum. Users could post questions about their home, energy use, or experiences, and receive answers from the resident experts and other users on the site.

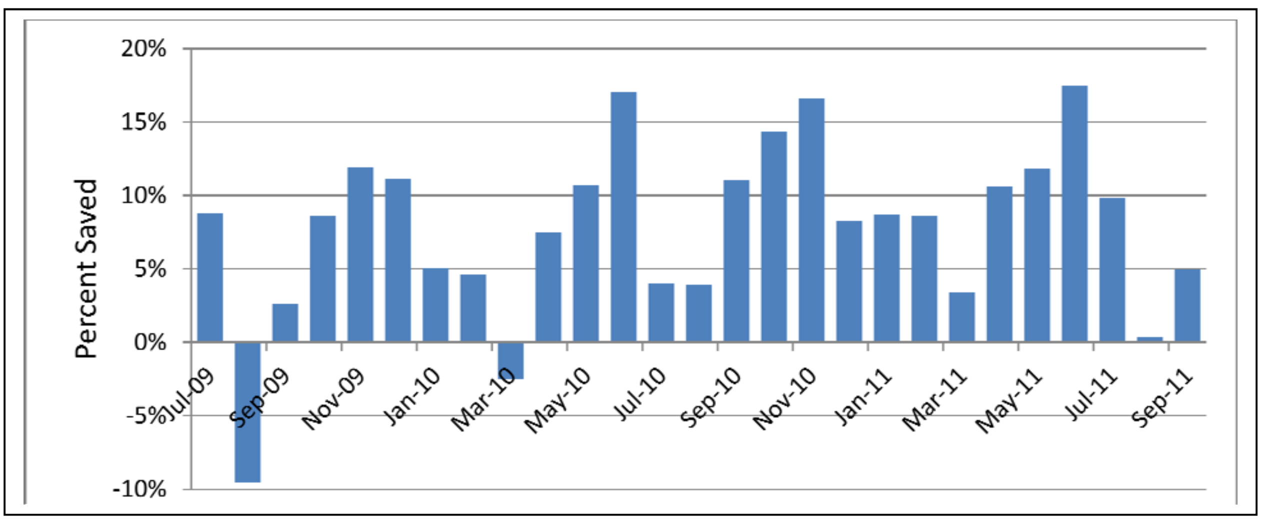
Informational Content and Savings Plan

Two of the primary sections of the website were *Learn and Save* and *Your Savings Plan*. Here, users could explore about 100 actions that they could take to save energy in their home. The actions contained a brief explanation of how a user would undertake the action, and how that saves them energy. The actions also had clearly explained savings assumptions and links to related resources. Users could add an action to their Savings Plan, and indicate if they were considering that action, committed to it, or if they had completed it. Users could also make their savings plan public in their user profile. These sections served to educate users about their energy consumption, and provide them with an opportunity to make a public commitment to take action.

Savings Analysis

A savings analysis was performed on the same population (n=91) as that examined in *Residential Smart Energy Monitoring Pilot Final Report* (PA Consulting Group 2010). Using two control groups, this study found savings of 9.3% over users' initial year on the website. A subsequent savings analysis was performed on the same population of users for 27 months after the start of the program. The control group data were not available, so savings were determined by calculating the change in consumption after the start of the program based on 12 to 36 months of baseline data. The savings analysis was performed using a modified version of the baseline development strategies detailed in Annex G of ASHRAE Guideline 14-2002 (ASHRAE Guideline Project Committee 14P 2002). Using this strategy each household's temperature responsiveness during the baseline period is determined using a change point procedure that identifies non-weather dependent baseline consumption, heating and/or cooling dependent consumption. For each month during the study period each household's consumption is predicted based on their original performance characteristics under current weather conditions. Savings were calculated as the difference between the actual and predicted consumption. This analysis demonstrates average monthly savings of 9% over the 27 months studied ($t(26) = 3.44$, $p < .001$) (See Figure 3). The savings show no sign of diminishing over time. While recent studies have found a wide range of savings from smart grid enabled feedback (with several studies showing much lower savings than 9%), these findings validate the strategy of providing feedback in conjunction with appropriate engagement strategies.

Figure 3. Percent Energy Savings By Month



Energy savings are determined by the difference between predicted and actual consumption for each month.
Source: Cape Light Compact and Tendril

Engagement Analysis and Lessons Learned

Lesson 1 – Engagement is High and Persistent

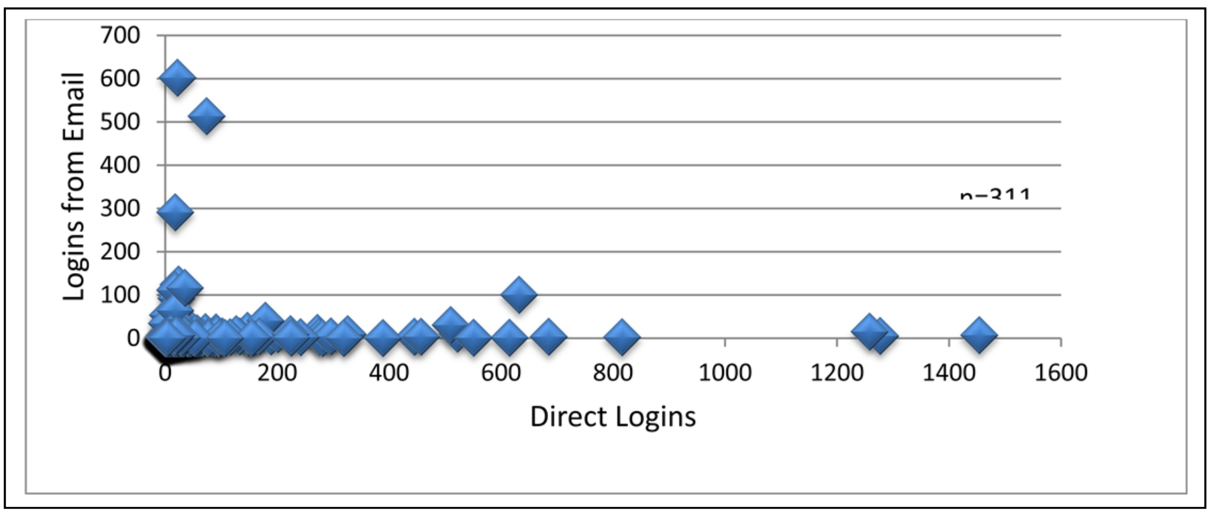
Engagement data (non-savings related) was collected from a group of 311 users. Ninety one of these users were with the original Cape Light Compact study. The other 220 were from pilot groups of municipal utilities in Eastern Massachusetts. The utilities chose to share a common site because the shared site experience increases social interaction by creating a larger community. Some elements of the site are shared by all users, others are only shared within a utility group.

On average, users logged in four times per month over the study period. We define impact opportunities as the number of times the user interacts with the application through the web or email - or the sum of logins plus emails. On average, each user had 15 impact opportunities per month. To track user engagement, a series of user "milestones" were examined. The milestones were the percentage of users who had logged in a total of 4, 12, and 52 times after 12 months. Eighty-two percent of users had logged in at least four times by 12 months, 57% had logged in 12 times, and nearly a quarter of all users had averaged one login per week after 12 months.

Lesson 2 – Emails Drive User Engagement and More Engaged Users Save More

Email access is a key indicator of engagement. All users received monthly email and nearly half of all users received daily or weekly e- mails. The users receiving daily and weekly emails rarely unsubscribed, and after the second month, they logged in at a higher rate than those users receiving only monthly emails. The importance of more frequent emails increases over time. After twelve months, a larger percentage of users who are receiving more frequent emails are logging in (36%) compared those receiving only monthly email (21%).

Figure 4. Logins from Email vs. Spontaneous Logins per User



Logins from email are those logins that resulted from clicking a link in an email. Direct logins did not come from a link embedded in an email. Source: www.save.groundedpower.com

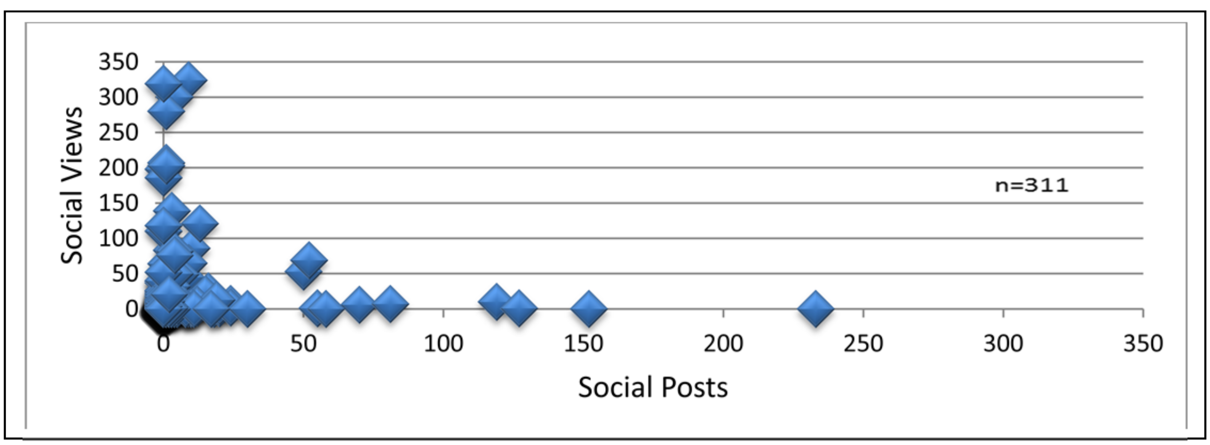
In addition to increasing logins, the data suggest that emails acted as a cue for a subset of users that might not have logged directly into the site without an email. Figure 4 shows a scatter plot of logins per user over 27 months that come directly from an email, against direct logins (those logins that do not originate with a link in an email). The figure shows two distinct populations that cluster around each axis. The larger population logged in to the website almost exclusively directly, while a smaller subset of the population logged in almost exclusively from links in emails. While not definitive, this pattern suggests the possibility that those users that logged in almost exclusively from emails would not have visited the site absent the emails. This supports the notion that a variety of ways of interacting with the website are necessary to maintain high levels of engagement across a population.

Further evidence for the role that emails played in driving additional logins lies in the correlation between the number of emails a user received in a given month and the number of logins. With an r value of 0.2574 ($p<.005$), email frequency accounted for about a quarter of the variability in login activity. While we did not find a significant correlation between the number of emails received and savings, there was a modest but significant correlation (r=0.2147, $p<.05$, one tailed) between the average logins per month and percent savings.

Lesson 3 – Many People Are Watching the Conversation

In a given month between 10% and 25% of users that logged in took a snapshot, made a comment, or posted to the expert forum. While those values are modest, the data suggest that the social features brought value to many more users on the site than just those that created social content. In a given month between 35% and 55% of users that logged in viewed social content, or about twice as many users as created social content. A scatter plot of each user's creation of social content against their viewing of social content suggests that many users viewed social interactions without ever contributing to the online conversation. Another group that stands out is the small handful of users that created a large number of social posts without viewing others' posts. These users are most likely members that took frequent (often daily) *snapshots* to catalog what happened in their homes (See Figure 5).

Figure 5. Social Views vs. Social Posts per User



Source: www.save.groundedpower.com

Lesson 4 - Users Are Experts Too, and Great Champions

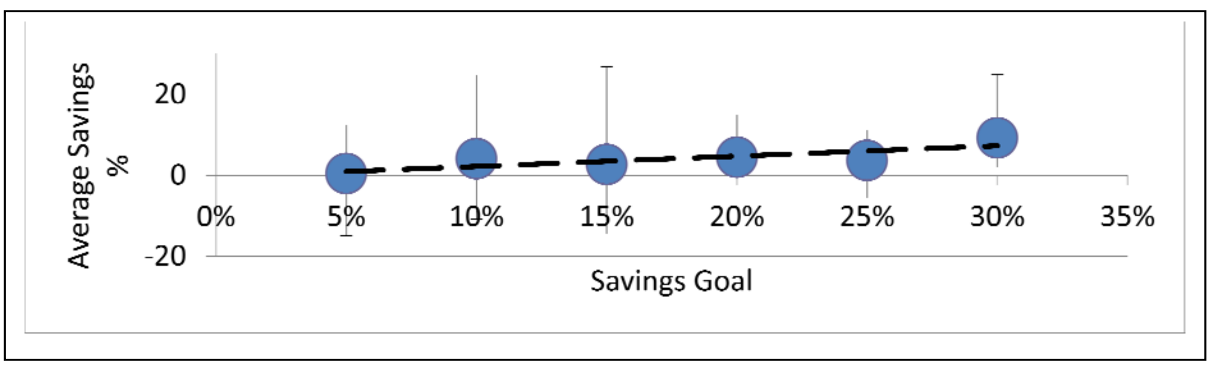
Two distinct populations emerged that did much to maintain the level of engagement with the website. One group was referred to as *expert users*, and the other as *super users*. *Expert users* brought genuine energy expertise to the community. They did not typically contribute to the day to day discussions on the site, but when an interesting question arose they stepped in to share their expertise (see User 2 in Figure 2 for an example). Resident experts stood ready to contribute to any conversation, but typically let *expert users* take the lead to build their reputation and rapport with the community. This was done with the belief that support from a fellow user will be more trusted, and therefore be more persuasive, than if it came from the resident expert. Resident experts would step in if important information was missing or the direction of the conversation was not likely to bear fruit.

Super users were a small subset of extremely active users. They were not necessarily energy experts, but they brought energy to the website that kept the conversation moving. They posted their own experiences, engaged in conversations with other users, and generally acted as a cheerleader for the other users on the site. These users may have accounted for a disproportionate amount of the social activity on the website, but they served an invaluable function of engaging with other users, and keeping them involved.

Lesson 5 -Crowdsourcing Works

One of the enjoyable phenomena observed on the website was community problem solving. Very frequently someone will post a snapshot that essentially said "I don't get what's going on here". Very often a half a dozen or more users shared their thoughts, and engaged the poster in a conversation about what was going on in their home at the time of the *snapshot*. In some cases an experimental procedure would be proposed to help the poster better isolate the mystery source of energy use. This kind of behavior showed the depth of exploration and commitment that some users had to understanding how their homes work, and how to reduce their energy consumption. It was through interactions like these that we also saw the diffusion of efficient technologies first hand. Users often mentioned positive experiences that they have had with efficient technologies. On occasion other users responded to these comments expressing a willingness to try a new technology based on their peer's recommendation.

Figure 6. Average Savings by Savings Goal



Source: www.save.groundedpower.com

Lesson 6 – Goals Matter

Earlier analysis of the savings achieved by this group found that goal setting had a significant impact on energy saved (PA Consulting Group 2010). The current analysis shows that this trend has persisted (see Figure 6). A simple correlation of savings goal with savings achieved found a highly significant relationship ($p<.005$) with the largest r value of any we measured ($R=.3727$). No further studies have been undertaken to establish the extent to which goals are simply a good predictor of savings, or if the continuous feedback of how users perform relative to their goal plays a role in motivating users to reduce their consumption.

Lesson 7 –Learning What Users Are Doing To Save Energy Is Still a Challenge

One of the interesting findings from the 2010 analysis of this group was that the efficient actions that users reported taking during the period of study did not differ from the actions of the control group (PA Consulting Group 2010). This highlights the difficulty of identifying exactly what changes users made in their homes. The application had a savings plan where users could indicate what actions they took in their homes. Users' use of the savings plan on the website was analyzed to see if any insight could be gained into how users changed their behavior. Specifically the analysis explored any relationship between use of the savings plan and energy savings, and if use of the savings plan could be used to determine what actions users were taking. No relationship between use of the plan and savings was found. A large majority of users used the plan during their initial weeks on the site; however, after their initial weeks on the site only a modest number of users added new actions to their plan or registered completion of actions. The minimal number of users that registered completion of actions made it impossible to draw meaningful conclusions from the use of the feature.

To get a sense of whether users were exploring their savings options but simply not changing their savings plans, an examination of page views of individual actions, savings plans, and the *Learn and Save* tab was undertaken. The *Learn and Save* tab contained a small collection of actions and was the gateway to all of the individual actions. Counting the number of users that interacted with at least one of those features in a given month suggests that almost three times as many people explored the actions available to them in a given month than added new actions, or registered completion of an action. That a high percentage of users used the savings plan initially is a strong indication of user interest, and a willingness to explore what their options are and commit to taking action. The fact that a relatively large percentage of users in a given month explored the actions available to them suggests that users continue to search for ways to save energy. However, the relative infrequency of user's registering actions taken after their initial weeks on the site suggests that there are design opportunities to bring users back to their plan to remind them of their commitments, persuade them to follow through and register the fact that they have completed an action.

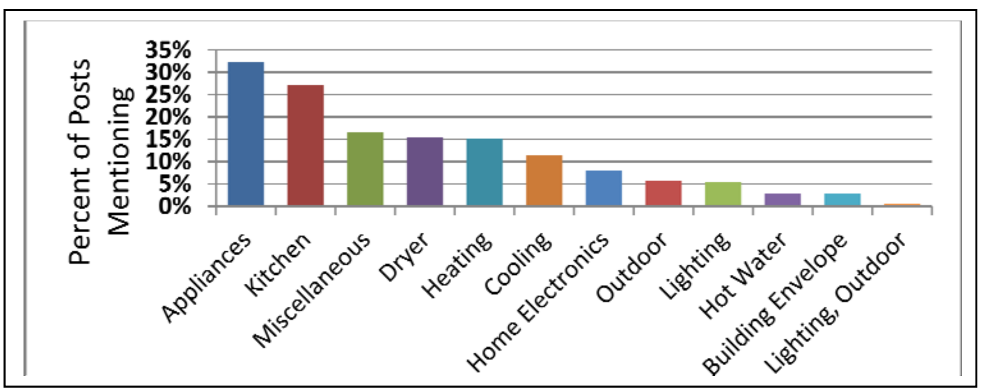
Lesson 8 – Experts Can Market Other Programs Too

The energy experts on the website answered technical questions from users, but they also tracked what users were saying on the website, and took part in the conversations when appropriate. A benefit of having an expert closely monitoring what users are discussing was that they could note when a user was likely to benefit from a traditional utility efficiency program, and point the user in the appropriate direction. Users appeared receptive to these interactions, and very often indicated that they intended to take advantage of a program when they learned of it. Examples of this ranged from informing a user that has decided to empty and unplug their second refrigerator that their utility has a refrigerator retirement and recycling program to pointing out to a user whose central air conditioner took 24 hours to cool his home that he would likely benefit from a home energy assessment. On this version of the website, this was a wholly manual effort with no tracking; however, there is clearly an opportunity to develop tighter integration with utility efficiency programs.

Lesson 9 –Power Catches the Eye, Energy Does Not

While not directly related to savings and engagement, this lesson stood out as one that should inform the design of future feedback mechanisms. Each social post on the website was categorized by subject matter to determine what users talked about on the website. The most interesting finding from this exercise was that the frequency with which a subject comes up in the social interactions on the website has much more to do with the power used by a device, as opposed to the amount of energy it is responsible for consuming. For instance dryers are mentioned in 15% of all posts but according to the EIA they account for only 3.7% of residential electricity consumption. Conversely, lighting is only mentioned in about 6% of all posts yet it accounts for 14.2% of residential electricity consumption (U.S. Energy Information Administration 2012). This appears to be due to the fact that changes in power create distinctive features on the consumption chart (See Figure 1), and the biggest power consumers create the most distinctive features. This highlights the importance of providing users with the appropriate context to the feedback they receive.

Figure 7. Average Savings by Savings Goal



Source: www.save.groundedpower.com

Conclusions

Our experience demonstrates that a goal-based method with interactive tools that lead to participation can result in significant long-term savings. We have shown that utility customers will actively engage with utility sponsored, social and interactive web applications, and, in the process, they will become energy savings advocates and share expertise with each other. The usage data indicate that active on-line participation benefits the broader population of users beyond those active participants. The correlation of engagement with savings indicates that social interaction is an important component of successful web-based, energy feedback interventions.

References

Allcott, H. 2011. "Social Norms and Energy Conservation." *Journal of Public Economics*, (95): 1082–1095.

ASHRAE Guideline Project Committee 14P. 2002. *ASHRAE Guideline 14-2002 Measurement of Energy and Demand Savings*. Atlanta, Ga.: American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.

Darby, S. 2006. *The Effectiveness of Feedback on Energy Consumption*. University of Oxford: Environmental Change Institute.

Ehrhardt-Martinez, K. K. A. Donnelly & J. A. Laitner 2010. *Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity-Saving Opportunities*. Washington, D.C.: American Council for an Energy-Efficient Economy.

Foster, B. & S. Mazur-Stommen 2012. *Results from Recent Real-time Feedback Studies*. Washington, DC: American Council for an Energy-Efficient Economy.

Hopper, J. R. & J. M. Nielsen 1991. "Recycling as Altruistic Behavior: Normative and Behavioral Strategies to Expand Participation in a Community Recycling Program." *Environment & Behavior*, 23(2), 195–220.

Lutzenhiser, L. & S. Bender 2008. "The "Average American" Unmasked: Social Structure and Differences in Household Energy Use and Carbon Emissions." In: *Proceedings of the ACEEE 2008 Summer Study on Energy Efficiency in Buildings*. Washington, D.C.: American Council for an Energy-Efficient Economy.

Morley, J. & M. Hazas 2011. "The Significance of Difference: Understanding Variation in Household Energy Consumption" In: *ECEEE 2011 SUMMER STUDY*. European Council for an Energy Efficient Economy.

PA Consulting Group. 2010. *Residential Smart Energy Monitoring Pilot Final Report*. Madison, WI: PA Consulting Group.

Rogers, E. M. 2003. *Diffusion of Innovations*. New York: Free Press.

U.S. Energy Information Administration. 2012. Estimated U.S. Residential Electricity Consumption by End-Use, 2010.

De Young, R. 1993. "Changing Behavior and Making It Stick: The Conceptualization and Management of Conservation Behavior." *Environment & Behavior*, 25(4): 485–505.

De Young, R. 1996. Some Psychological Aspects of Reduced Consumption Behavior: The Role of Intrinsic Satisfaction and Competence Motivation. *Environment & Behavior*, 28(3): 358–409.